VEGETATION RESPONSE TO A MOISTURE GRADIENT ON AN EPHEMERAL STREAM IN CENTRAL ARIZONA

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Abstract.— Ecological aspects of desert vegetation in relation to a moisture gradient along an ephemeral stream in central Arizona were investigated. The stream channel, flood plain, and north-, west-, south-, east-facing slopes represent a moisture gradient going from mesic to xeric conditions. Vegetation in some areas of the stream channel intergraded into flood plain vegetation, which in turn intergraded into slope vegetation types. In other areas there were sharp delineations between stream channel and flood plain and between flood plain and slope. Trees and legume species preferred midmoisture habitats, but forbs, shrubs, and succulents preferred dryer areas. Family groups like the Asteraceae and the Poaceae were found to be distributed ubiquitously. Niche widths were broadest for flood plain species. Diversity was highest on the slopes. Negative correlations existed between stand diversity and the Synthetic Stand Moisture Index (i.e., as moisture increased diversity increased). It is believed that disturbance as well as moisture influenced diversity.

Central and southern Arizona are considered to be part of the Sonoran Desert, which occupies much of the southwestern United States and northern Mexico. Physiographically, the area is characterized by small mountain ranges rising above level basins and by a vegetation comprised of shrubs, small trees, cacti, and associated ephemerals. The level basins are now liberally marked by arroyos or wadis (i.e., dry washes cut by the action of ephemeral streams). Bryan (1928) suggests that the arroyo cutting is of recent origin.

The rainfall pattern of the Sonoran Desert exhibits two distinct peaks: (1) a summer rainy period from July to September characterized by thunder storms of short duration and heavy rainfall intensity, and (2) the gentle rains of December through March caused by the southward movement of subtropical high pressure systems. Summer rains which are of greater intensity vary less from year to year than do the winter rains (Mallery 1936a). Localized storms in the region are very pronounced, often being limited to a few square miles.

Temperatures in the Sonoran Desert are characterized by great diurnal fluctuations, hot summers and warm winters. Freezing temperatures may occur, but without regularity and they do not last for extended periods of time.

Vegetational descriptions of the Sonoran Desert in part at least include Nichol (1952), Whittaker and Niering (1964, 1965), Marks (1950), Glendening and Paulsen (1955), Little (1950), Kramer (1962), Richards (1925), and Shreve (1922, 1924). Spalding (1910), Blumer (1909, 1910) and Walmo (1955) briefly mention desert vegetation in foothill sites they studied in the southern Arizona mountain ranges. Keil (1970) and Letho (1970) recently completed floristic studies in two areas of the Sonoran Desert located in Maricopa County.

Ecological studies dealing with isolated fragments of Sonoran Desert ecosystems are more numerous than are those dealing with community dynamics or entire community structure. For example, germination studies of annuals (Klikoff 1966, Capon and Asdell 1967, Beatley 1967, Went 1942, 1948, and 1949, Went and Westgaard 1949, Juhren et al. 1956, and Trevis 1958a, 1958b) and of perennials (Turner 1963, Shreve 1931, Turner et al. 1966, and Barbour 1968) have been done. Productivity studies of perennials (Chew and Chew 1965) and their ecology in relation to soil types, mineral nutrients, water

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relations, and plant associations (Yang 1950, Livington 1910, Yang 1957, Gardener 1951, 1959, Spalding 1909, Yang and Lowe 1956, Rich 1961, Reynolds 1962, Muller and Muller 1956, Dalton 1962, Wilm 1956, Parker and Martin 1952, Reynolds and Tshirley 1957, and Halvorson and Patten 1974) have also attracted interest. Work with climatic factors in desert areas has been completed by Smith (1956), Sellers (1960), Humphrey (1933), and Mallery (1936a, 1936b). Niering et al. (1963), Turner (1963), and Halvorson (1970) have briefly discussed the pattern of vegetational change from mountain slopes down onto the basin floors. However, their discussions are limited to population dynamics and vegetation studies of foothills and mountain slopes.

Halvorson (1970) indicates that the valleys and mountains of central Arizona have not been studied in detail as is the case with the mountain and foothill areas in the more southern portions of the state (see Whittaker and Niering 1964, 1965, Niering et al. 1963, Spalding 1909, 1910). The purpose of this study was to describe the vegetational zonation patterns existent along an ephemeral stream in central Arizona and to determine whether the observable vegatational patterns represented a continuum adapted to a moisture gradient from slope to stream channel or if they represented distinct, discrete communities.

Study Area

The study area lies in a foothill region of the Sonoran Desert and is part of the Mexican Highlands, a subdivision of the Basin and Range Province, which is geographically located to the west and south of the Colorado Plateau (Halvorson 1970).

The area of study is a five-mile section of New River, an ephemeral stream located 35 miles north of Phoenix, Arizona (Fig. 1). This section of the river parallels Interstate 17 for 2.5 miles and then bends away following Table Mountain and paralleling Table Mesa Road (Fig. 1). New River is a tributary of the

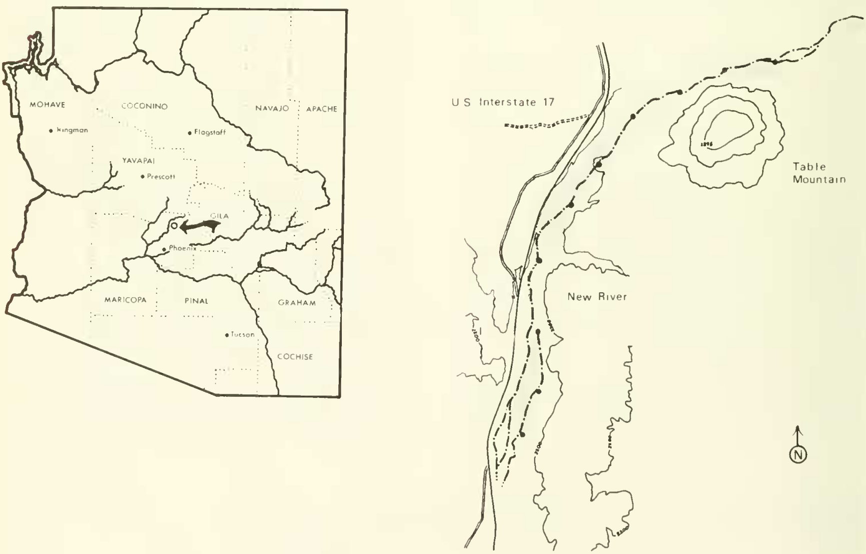

Fig. 1. Map of the study area showing location in Arizona.

Agua Fria River, which feeds into the Gila river and drains most of Central Arizona.

Metamorphic, igneous, and sedimentary rock comprise the parent material through which the Gila River and its tributaries flow. Davis (1925) proposed the origin of the existing mountain ranges to be tilted and moderately dissected fault blocks. From such ranges the broad desert basins have derived their soil, collected from alluvial material eroded from adjacent mountain slopes. The soils in the study area are generally shallow and poorly developed. Desert pavement is a prominent feature in the area and, as is the case in many desert areas, a narrow surface horizon exists in association with a caliche near the soil surface. The area has been subjected to grazing by domestic livestock since the 1800s. Location 2 of the study area is in close proximity to the site of an old stage station. Much of the area is now controlled by the Tee Cattle Company.

Methods

Ten study sites were located at one-half-mile intervals along a five-mile section of New River (Fig. 1). Five stands were selected at each site, one stand each at the following locations: both slopes adjacent to the stream channel, the flood plain on both sides of the stream channel, and the stream channel itself. In each stand, three 5 × 10 m plots were set up approximately 3 m apart. Four quadrats, each 1 m square, were placed inside each large plot. Trees and treelike vegetation were sampled within the large plots, and small shrubs, forbs, and grasses were sampled using the meter square quadrats. Frequency data were taken and used in the analysis.

Vegetation patterns were analyzed through the use of a synthetic moisture gradient. The moisture gradient was established through knowledge gained from the literature (Niering et al. 1963) and from work done in the field. The stream channel was selected as being the most moist. The two flood plain units were lumped together and considered the next most moist. In most north temperate floristic systems, the north-facing slopes are considered to be more moist than the opposite south-facing slopes (Daubinmire 1974). Such considerations are generally attributed to a shadowing effect of the hills and mountains that prevent direct sunlight from ever reaching the area. A similar relationship has been noted with east- and west-facing slopes. However, because of the peculiar shadowing effect of the adjacent hills noted in the study area, it was felt that the east-facing slope would exhibit the dryest conditions, with the west-facing slope fitting in between the north- and south-facing slopes on the moisture gradient. Those stands common to each area (i.e., stream channel, floodplain, etc.) were lumped together and average frequency values for each species in the area were computed. The species were then arranged in order of their occurrence in the six areas (Table 1). Those species most frequent in the stream channel were segregated to the top of the table and those most frequent on the east-facing slope were placed near the bottom, with all others falling somewhere in between. From this table indicator species were selected using as a basis frequency values approximately twice that in one group as in any other. The indicator species were then weighted with an index number. The index number was determined as follows: the stream channel species, selected as being representative of the most moist areas, were assigned the index number 5; the flood plain species in the next most moist area were assigned the number 4; and so on with the species of the east-facing slope receiving the number 0. When the frequency value of a species was not twice that of the next highest group, yet was greater and formed the apex of an increased upward trend, the species was assigned an index number midway between those for the groups in which the two largest frequencies were found and included as an indicator.

Synthetic Stand Moisture Index values (SSMI), similar to Plot Index Values (PIV) described by Dix and Butler (1960), were constructed by dividing the sum of the composite indices for all indicator species found in a stand by the sum of the stand frequencies of those indicator species found in that stand. The composite index values were determined by multiplying the stand frequency of an indicator species by its moisture index number. Therefore,

$$\text{SSMI} = \frac{\Sigma \text{ composite index values for indicator species}}{\Sigma \text{ frequency values for indicator species}}$$

SSMI values were computed for all stands. The stands were then placed along a one-dimensional ordination in an attempt to relate the stands spatially. Indicator species and other vegetational parameters were then graphed against the ordination in an attempt to elucidate trends. Average frequency values were computed for all stands falling between the SSMI values of 0 to 1, 1 to 2, 2 to 3, 3 to 4, 4 to 5, on the moisture gradient. This method was employed because it showed trends much more clearly than the entering of all points.

Cluster analysis techniques (Sneath and Sokal 1963) were applied to similarity index figures obtained by utilizing Sorenson's index of similarity (Sorensen 1948) and the following equation from Dix and Butler (1960):

$$K = \frac{2W}{a + b} \times 100$$

TABLE 1. Average percent frequency values for species distributed in the six groups used to establish the synthetic stand moisture gradient. Numbers to the left of the species names represent index numbers assigned to those species selected as indicator species of the different groups.

		Average percent frequency					
				Slope			
	Species	River bottom	Flood-plain	North	West	South	East
5	*Baccharis glutinosa*	83	33	0	0	0	0
4.5	*Baccharis sarothroides*	55	33	0	0	0	0
4.5	*Hymenoclea monogyra*	45.5	35.4	0	0	0	0
5	*Salix* sp.	33 2	0	0	0	0	0
4.5	*Polypogon monspeliensis*	25	14.6	0	0	0	0
5	*Euphobia* sp.	19.5	8.3	0	0	0	0
	Bromus rubens	16.7	15.9	12.5	0	0	8.3
4.5	*Minulus glabratus*	10.4	8.3	0	0	0	0
4.5	*Datura meteloides*	8.3	8.3	0	0	0	0
	Marrubium vulgare	0	8.3	0	0	0	8.3
	Mammillaria microcarpa	0	8.3	0	8.3	0	8.3
4.5	*Avena fatua*	0	8.3	0	0	0	0
3	*Ephedra viridis*	0	8.3	8.3	8.3	0	0
	Lepidium sp.	8.3	13.9	8.3	0	0	0
4	*Franseria ambrosioides*	0	19.8	0	0	0	0
4.5	*Cynodon dactylon*	16.5	25.2	0	0	0	0
4	*Platanus wrightii*	0	33	0	0	0	0
	Lycium fremontii	0	53.7	33	44.3	33	33
	Acacia greggii	0	62.2	0	66.7	0	0
	Prosopis juliflora	33	76.1	49.5	66.7	58	61
	Simmondsia chinensis	0	55	69.8	58.5	33.2	66.2
	Cercidium microphyllum	0	49.6	66.5	46.5	58	58
	Schismus barbatus	13.8	37	56.2	19.4	30.2	41.5
2.5	*Ferocactus wislizeni*	0	8.3	33	37.1	8.3	8.3
2.5	*Eriogonum fasciculatum*	0	0	38.8	33.3	8.3	0
	Larrea divaricata	0	43.3	49.5	49.5	0	51.4
1	*Eriogonum* sp.	0	0	0	0	25	8.3
	Plantago purshii	0	26.1	16.7	32	38.9	33.2
1	*Opuntia leptocaulis*	0	0	0	8.3	58.3	16.7
	Opuntia engelmannii	0	16.7	0	26.8	66.7	20.6
	Opuntia bigelovii	0	33	55.5	66	82.5	52.1
1.5	*Fouquieria splendens*	0	0	55.6	66	100	0
	Salsola kali	0	0	0	0	0	16.6
0.5	*Enchinocereus engelmanii*	0	8.3	0	8.3	16.7	24.9
	Carnegiea gigantea	0	40.3	0	33	33	49.5
0	*Opuntia fulgida*	0	33	0	33	33	66.5
1	*Franseria deltoidea*	0	30.1	8.3	59.7	56.5	80.0

where "K" equals the index of similarity, "a" is the frequency of all species in one stand, "b" is a similar figure for a second stand, and "W" is that part held in common by both stands.

Analyses of the similarity index values and the cluster techniques were carried out on an IBM 7030 computer.

Niche width and stand diversity values were computed using the equation $B = 1/\Sigma pi^2$ where "B" is equal to either the niche width and/or diversity and "pi" is a measure of the relative abundance of a species in a given habitat (Levins 1966, MacArthur 1972). Niche width values for a species were obtained by summing its pi values across all stands. Diversity values, on the other hand, were computed by summing the pi values for all species found, in a single stand.

The P × F (Presence × Frequency) index (Anderson 1964, Curtis 1959) was computed for all species found in the study area to give an indication as to species importance in the system (Table 4).

Diversity Indices (DI) were compared to the SSMI by regression analysis (Hall 1971, Dick 1971) to determine if any relationship existed between the two measures. Species determinations follow Kearney and Peebles (1951).

Results and Discussion

The five-mile section of New River presents a study in contrasts. Characteristically the flood plain tends to be wide in some areas and narrow in others. The vegetation along the wide areas intergrades readily with that of adjacent slopes, but sharp lines of demarcation appear between flood plain and slope vegetation where the flood plain narrows. The flood plain exhibits a wide variety of vegetational pattern. The broader areas display vegetation types closely allied to those of adjacent slopes, with the narrow areas exhibiting greater densities of trees, shrubs, and thicket-forming plants. The river channel itself is wide, sparsely vegetated, and disturbed periodically by high water flow resulting from heavy rains in the mountains, evidenced by the highly sorted sand, gravel, and rocky nature of the channel substrate. Seep areas in the channel are characterized by the presence of water nearly year-round. In these areas larger trees such as *Salix spp.* and *Platanus wrightii* are found along with *Mimulus glabratus* and *Baccharis gulutinosa*. The north-, west-, south-, and east-facing slopes in that sequence appear to be in order of decreasing moisture. Differences in ground cover, the number, and types of individuals on the slopes is apparent. The north-facing slopes generally exhibit a larger more mesophytic flora.

Vegetation analysis involved establishing a synthetic moisture gradient. This was accomplished by arranging species in order of moisture delineations and assigning index numbers (Table 1). Synthetic Stand Moisture Index values (SSMI) were then computed for all stands (Table 2). Using these values the stands were placed on a one-dimensional ordination along the proposed moisture gradient, which oriented them spatially to each other (Fig. 2). Average frequency for indicator species and life form groups in all stands were then graphed against the one-dimensional ordination.

Species and life form groups were found to peak in importance along sections of the gradient (Figs. 3–4). *Franseria deltoidea*, for example, is well adapted to the dryest moisture regime on the gradient, but *Baccharis sarothroides* occurs in more moist sites. Figure 3 also depicts the relationships of several of the indicator species (i.e. *Fouquieria splendens*, *Ferocactus wislizeni*, and *Cercidium microphyllum*), for those stands of the study area occurring between 1 and 2 on the moisture gradient. Other species exhibiting similar patterns to those in Figure 3 were *Opuntia leptocaulis*, *O. bigelovii*, *O. engelmannii*, and *Plantago purshii* (Table 1). Also shown are the patterns exhibited by index plants (i.e., *Franseria deltoidea*, *Opuntia fulgida*, etc.) of the gradient class, 0 to 1. Species showing similar patterns were *Salsola kali* and *Carnegiea gigantea*. The species *Hymenoclea monogyra* and *Cynodon dactylon* showed peak prefence in the most moist areas (Fig. 3). *Baccharis glutinosa*, *Salix spp.*, *Euphorbia spp.*, *Mimulus glabratus*, and *Dature meteloides* are other species found to exhibit similar patterns. *Franseria ambrosioides* (Fig. 3) peaked between the SSMI values of 3 and 4, which represents the flood plain area of the study. Other species prefering this same habitat were *Acacia greggii* and *Simmondsia chinensis.* It should be noted, however, that these two species are rather ubiquitous and may be prominent in other areas as well. *Schismus barbatus* and *Eriogonum fasciculatum,* though not clear-cut index plants of the west and south slopes (there were no clear-cut indicators for this section of the gradient), show optimum frequency peaks in this area.

Because the relationship between various

Table 2. Stands listed along with their Synthetic Stand Moisture Index values (SSMI), diversity indicies, aspect and/or topographic position on the landscape. EF = east facing slope, SF = south facing slope, WF = west facing slope, NF = north facing slope, FP = floop plain, and SC = stream channel.

			Diversity				Diversity
Stand No.	SSMI	Location°	Index	Stand No.	SSMi	Location	Index
1	1.0	EF	5.886	25	4.5	RB	3.019
2	1.0	EF	4.970	26	4.5	RB	2.062
3	.91	Ef	5.394	27	0	RB	0
4	0	EF	4.003	28	4.6	RB	2.538
5	.50	EF	6.270	29	4.7	RB	3.019
6	.83	EF	9.452	30	4.6	RB	3.331
7	1.0	SF	5.388	31	4.5	FP	5.160
8	1.3	SF	5.504	32	4.2	FP	1.790
9	1.0	SF	6.515	33	.90	FP	7.457
10	.67	SF	9.050	34	2.2	FP	9.461
11	1.0	FP	4.988	35	4.5	FP	7.530
12	2.8	FP	5.643	36	2.9	FP	2.173
13	2.8	FP	7.348	37	3.9	FP	4.137
14	4.1	FP	4.160	38	.90	FP	6.357
15	1.0	FP	8.446	38	5.0	FP	4.798
16	1.2	FP	6.826	40	1.0	WF	7.819
17	2.1	FP	6.506	41	1.0	WF	8.184
18	3.6	FP	4.653	42	1.0	WF	5.063
19	4.4	FP	4.909	43	1.0	WF	5.131
20	0	FP	3.266	44	1.0	WF	2.507
21	4.8	SC	6.400	45	1.8	WF	6.053
22	4.8	SC	3.263	46	1.6	NF	6.169
23	4.5	SC	3.693	47	1.2	NF	6.105
24	4.6	SC	4.602	48	1.6	NF	3.949
				49	.50	NF	5.385

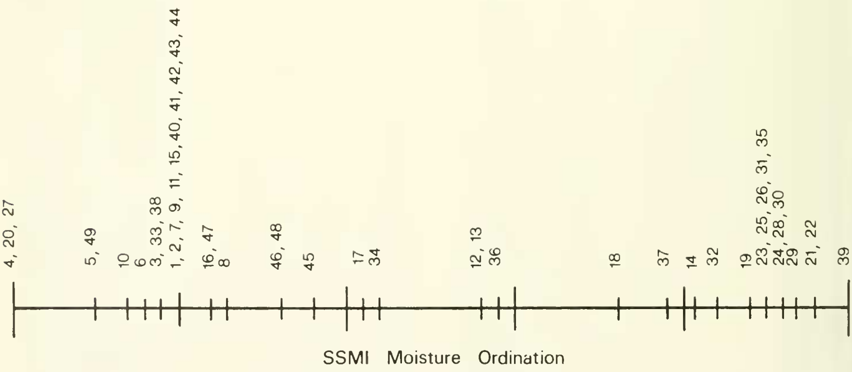

Fig. 2. One-dimensional ordination by SSMI values of stands along the moisture gradient.

life form groups and the moisture gradient was of interest, six groups were chosen—i.e., shrubs, succulents (cacti and cactuslike plants), trees, woody plants, forbs, and selected plant families (i.e., composites and legumes). Figure 4 shows great similarity between the established pattern for trees and that of legumes. It should be noted that the number of species these two groups had in common was high. Of further interest is the fact that the two groups contain species characteristic of the north-facing slope and of me-

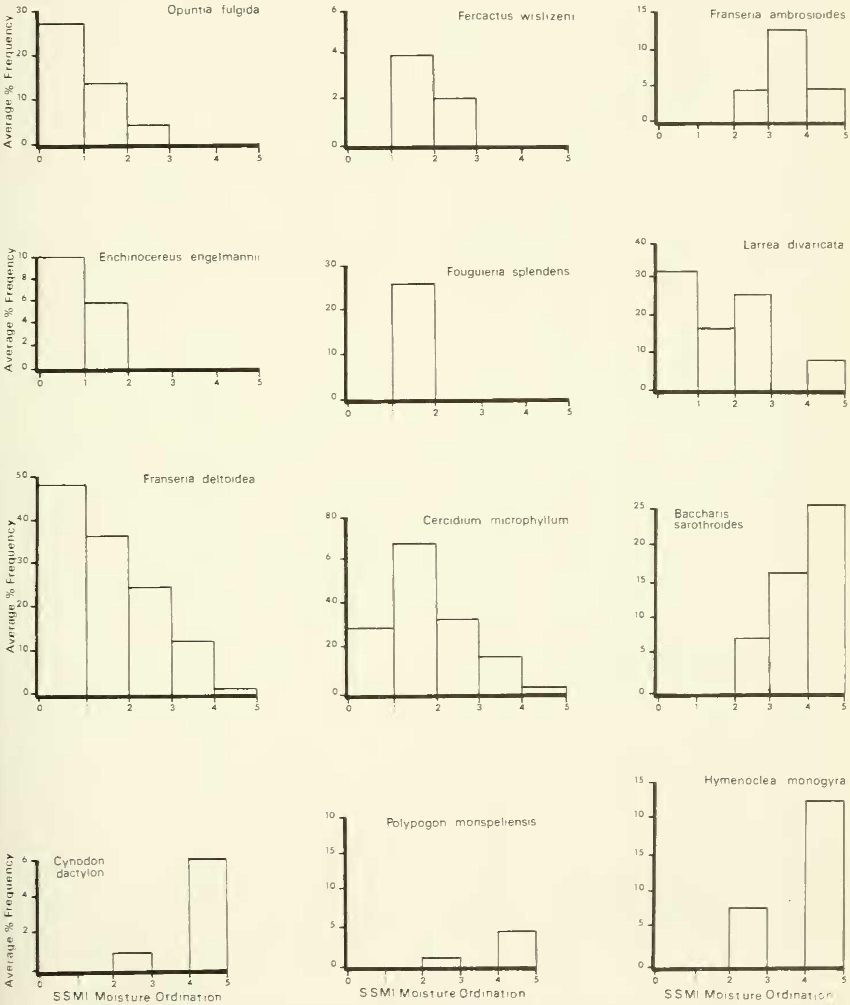

Fig. 3. Average percent frequency for indicator species plotted against the moisture gradient.

dium moisture regime preference. The shrubs, succulents, forbs, and woody plants as groups (Fig. 4) tend to prefer the dryer moisture habitats. The composites (as well as other family groups such as the grasses) showed no preference for particular sections of the moisture gradient and exhibited, as groups, rather ubiquitous distribution patterns in relationship to the SSMI gradient.

When cluster analysis techniques were applied to the 37 species (Fig. 5), five major groups were apparent; however, a few species did not relate well to any group. From left to right on the dendrogram the groups are: (1) predominately flood plain and lower bajada species, which include *Acacia greggii*, *Larrea divaricata*, *Schismus barbatus*, *Cercidium microphyllum*, and *Carnegiea gigantea*; (2) north- and west-facing slope species, which include *Fouguieria splendens* and *Eriogonum fasciculatum*; (3) south- and east-facing slope species, which include *Enchinocereus Engelmannii* and *Opuntia leptocaulis*; (4) flood plain species, which include *Bromus rubens* and *Franseria ambrosioides*; and (5) the stream channel species *Cynodon dactylon*, *Salix spp.*, and *Hymenoclea monogyra*. The relationships of these five groups to the established moisture gradient are depicted in Figure 6. As can be seen, all sections of the proposed moisture gradient are represented.

When the dendrogram (Fig. 7) for the 49 stands was constructed, five groups were again recognized. Table 3 indicates how these groups relate with regard to the topography of the study area. From the cluster analysis it appears that the west-, south-, and east-facing slopes were highly similar in vegetation types, and that those stands which were subjectively picked as being similar at the beginning of the study are in fact grouped together by cluster analysis. This

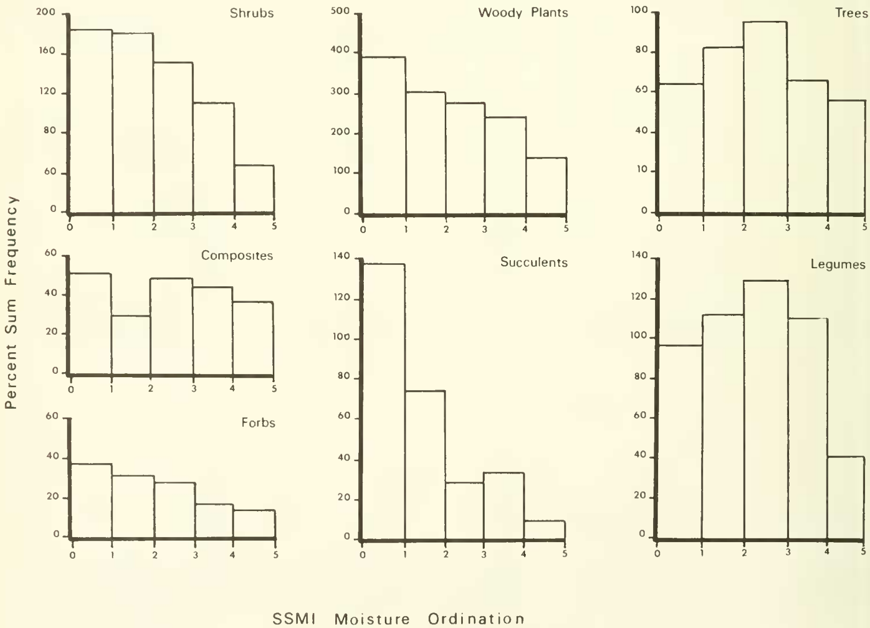

Fig. 4. Average percent frequency of life form groups plotted against the moisture gradient.

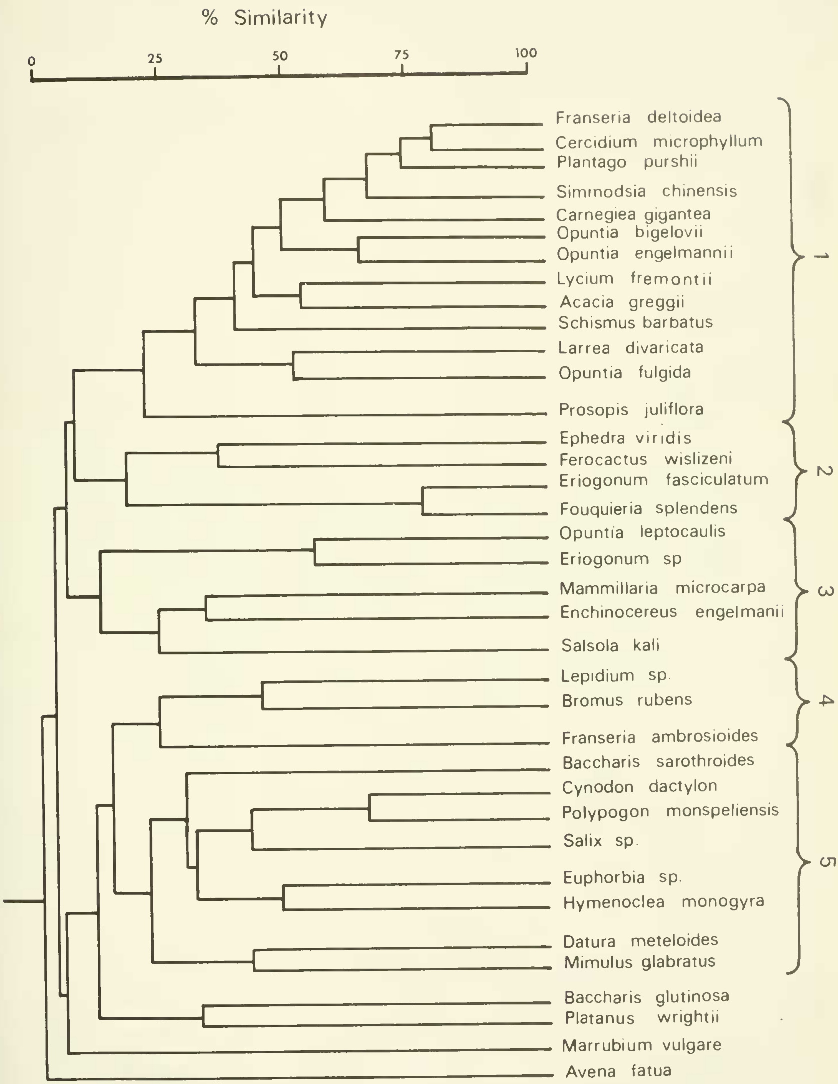

Fig. 5. Dendrogram of "cluster" analysis of 37 species.

would, of course, be expected if one assumes that the vegetation of an area reflects the general pattern of its abiotic environment (Niering et al. 1963).

Figure 8 illustrates niche width relationships to moisture preference. Flood plain species exhibit the broadest niche widths when compared with slope and stream channel species. Cluster analysis (Fig. 5) grouped species with similar niche widths together. Table 4 ranks all species in order of decreasing niche width and further serves to illustrate the point that those species with the broadest

Table 3. Dendrogram groups as designated in Figure 7, along with included stands and their predominant aspect and/or topographical location.

Dendrogram Group #	Stand #	Predominant location
1	21, 22, 23, 24, 25, 26, 28, 29, 30, 39	River channel
2	4, 11, 12, 13, 14, 18, 31, 32, 36, 37	Floodplain
3	1, 2, 3, 5, 6, 7, 8, 9, 10, 15, 16, 17, 33, 40, 41, 42, 43, 44	Slopes (east, south, west)
4	20, 38, 19, 34, 35	Floodplain
5	45, 46, 47, 48, 49	North-facing slope

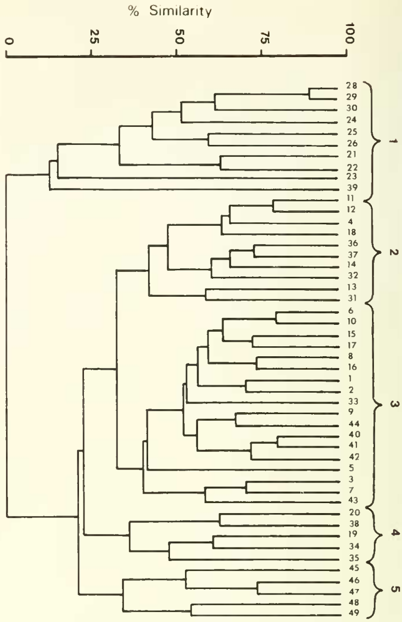

Fig. 7. Dendrogram of "cluster" analysis of 49 study plots.

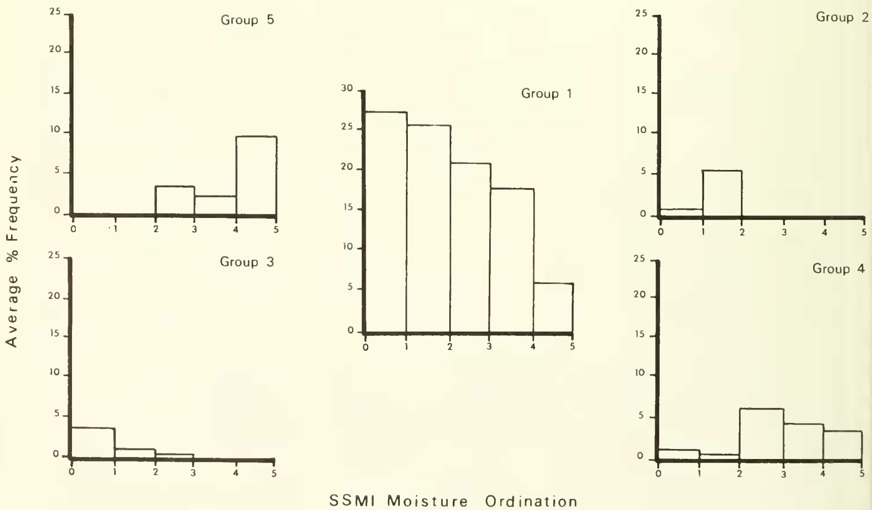

Fig. 6. Average frequency of cluster group species plotted against the inferred moisture gradient.

niches are, generally speaking, flood plain species. As indicated earlier, the flood plain includes a wide variety of habitats and it may be this fact that influences the broadest niches being noted in the flood plain.

Table 5 gives figures for the means ($\bar{x}$) and standard deviations for NW, SSMI, and DI figures. Regression analyses indicated that the NW vs. SSMI values exhibited highly significant correlations ($p < .001$). When niche

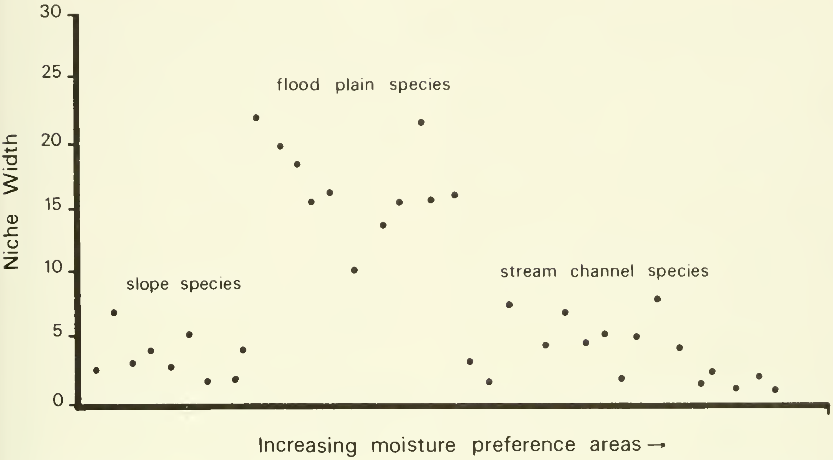

Fig. 8. Average diversity index values and average niche width values plotted against the moisture gradient.

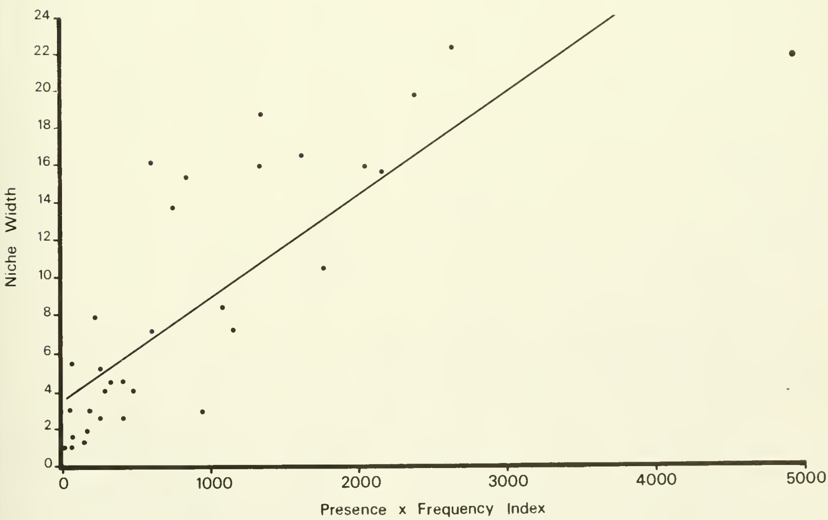

Fig. 9. Regression analysis of the relationship of NW vs. P × F index.

width measurements were compared by regression analysis to the P × F index values (Table 4 and Fig. 9), the relationship was again highly significant ($p < .001$) with an r^2 value of .68. It appears that the two parameters generally express similar information in terms of species importance in a community.

The relationship of the Diversity Index (DI) parameter to stand placement along the moisture gradient is illustrated in Fig. 10. As

TABLE 4. List of species encountered in the study, along with their niche width, percent presence, average percent frequency, and presence times frequency (P×F) index. Species are ordered in decreasing value of niche width.

Species	Niche width	Percent presence	Average frequency	P×F index
Acacia greggii	22.359	73.5	67.4	4954
Franseria deltoidea	22.293	57.1	45.9	2620
Cercidium microphyllum	19.724	42.9	55.2	2368
Plantago purshii	18.720	49.0	27.4	1343
Carnegiea gigantea	16.529	38.3	41.7	1618
Bromus rubens	16.152	42.9	13.9	596
Schismus barbatus	15.962	46.9	28.6	1341
Larrea divaricata	15.949	36.7	55.2	2044
Simmondsia chinensis	15.657	30.6	70.6	2160
Lycium fremontii	15.314	32.7	25.4	831
Opuntia engelmannii	13.648	18.4	40.3	742
Opuntia begelovii	10.483	28.6	61.6	1742
Hymenoclea monogyra	8.389	22.4	48.1	1077
Lepidium sp.	7.886	20.4	10.8	220
Prosopis juliflora	7.227	18.4	62.7	1154
Baccharis sacrothroides	7.184	14.3	42.4	606
Fouquieria splendens	5.450	8.2	57.8	66
Polypogon monspeliensis	5.391	18.4	18.5	340
Euphorbia sp.	5.181	14.3	17.8	225
Cynodon dactylon	4.518	18.4	22.2	408
Franseria ambrosioides	4.466	16.3	19.6	319
Mammillaria microcarpa	4.000	8.2	57.8	474
Ferocactus wislizeni	4.000	14.3	20.1	287
Datura meteloides	4.000	6.1	8.3	51
Ephedra viridis	3.006	6.1	8.3	51
Enchinocereus engelmannii	2.986	12.2	15.6	190
Opuntia fulgida	2.910	20.4	46.3	945
Baccharis glutinosa	2.575	6.1	66.5	404
Eriogonum fasciculatum	2.571	8.2	31.2	256
Marrubium vulgare	2.000	4.1	8.3	34
Opuntia leptocaulis	1.853	6.1	27.7	169
Eriogonum sp.	1.579	4.1	16.7	68
Salsola kali	1.577	4.1	16.7	68
Mimulus glabratus	1.293	16.3	9.4	153
Avena fatua	1.000	2.0	8.3	17
Salix sp.	1.000	2.0	33.0	66
Platanus wrightii	1.000	2.0	33.0	66

TABLE 5. Mean (X) and standard deviation (SD) values for the diversity indices (DI), synthetic stand moisture indices (SSMI), and niche widths (NW) as computed for stands grouped in cluster analysis (Figure 7 and Table 3).

	DI		SSMI		NW	
Groups°	X	SD	X	SD	X	SD
1	3.67	1.27	4.25	1.18	8.36	5.82
2	4.58	1.74	2.98	1.46	13.90	6.84
3	6.47	1.73	1.02	.31	14.98	6.44
4	6.30	2.35	2.40	2.03	12.48	6.32
5	5.54	.97	1.34	.52	11.69	7.41

opposed to niche widths, stand diversity was highest in the bajada and slope stands. In tropical ecosystems high uniformity is positively correlated with high diversity (MacArthur and Wilson 1967). However, in north temperate systems this relationship appears to be reversed—i.e., low uniformity yields high diversity (Dick 1971, Hall 1971). The data from our study seem to follow a similar pattern. There are, however, other parameters not measured in this study (i.e., disturbance as indicated by the presence of the introduced species *Avena fatua* and *Bromus rubens*, etc.) which, it is felt, have influenced the diversity trends of the area.

Conclusions

It is apparent that the stream channel has a set of species (among which are *Polypogon monspeliensis*, *Datura meteloides*, *Baccharis glutinosa*) distinct in many ways from those in the other areas; yet all are clearly a part of an integrated system. For example, *Bromus rubens*, *Cercidium microphyllum*, and *Acacia greggii* grow not only in the stream channel but also on the flood plain and slopes. The flood plain is highly varied in habitat, resulting in a mosaic of types. Some of the stream channel vegetation intergrades only into the flood plain, and the flood plain vegetation in turn intergrades into slope vegetation, especially where the plain is wide. In some locations where it is narrow the change between flood plain and channel vegetation or between flood plain and slope plain is sharply delineated, so that one can easily delineate channel food plain or slope vegetation. In other areas the flood plain is broad and the change from channel to flood plain to slope is so gradual and smooth that one is hard put to find where the stream channel ends and the flood plain begins. Due to the wide variety in habitats on the flood plain those species that are found to be ubiquitous throughout the flood plain region exhibit the broadest niche. Such species (i.e., *Acacia greggii*, *Cercidium microphyllum*, *Larrea divaricata*) with broad niche widths were predominately species of importance in the flood plain and lower bajada. Where the slope is distinct from the flood plain, it is clearly more sparsely vegetated than the flood plain and is dominated by several small shrubs. *Franseria deltoidea* is most prominent in these areas. In still other locations there exists a mixture of many species wherein no one species distinctly dominated.

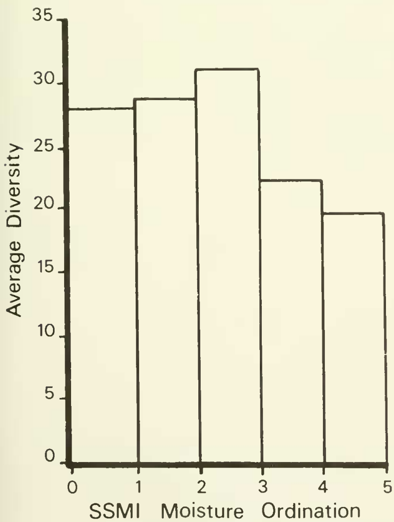

Fig. 10. Niche width (NW) plotted against species arranged by dendrogram sequence.

Species of similar life forms and taxa often showed similar location preference. Family groups in general, however, were ubiquitous and everywhere present. For example, the composites, as a family, are probably the most prevalent group in the study area and showed no identifiable trends. Other prominent families are the Poaceae and the Fabaceae. The grasses, though ubiquitous in distribution, showed no decided location preference. The legumes, on the other hand, appear to prefer medium moisture areas. With many of the legumes being trees or treelike forms, the arbrorescent life form also exhibited medium moisture preferences. Surprisingly, the forbs preferred the dryer moisture areas; however, this may be due to factors other than moisture. Succulents which are predominately cacti preferred the dryer moisture regimes. *Carnegiea gigantea*, one of the more prominent cacti on the area, exhibited its highest frequency value on the slopes. It did, however, extend onto the flood plain in some locations. Shrubs, as a group, represented by species like *Franseria deltoidea*, *Larrea divaricata*, and *Franseria ambrosioides* also preferred the dryest moisture areas.

Cluster analysis results were useful in that they substantiated many assumptions of the initial hypothesis which were subjectively stated. Species when clustered together exhibited similar niche widths and were also observed to occupy habitats in similar topographical locations. Stands when clustered produced groups which correlated to all sections of the moisture gradient. This evidenced that the gradient (though synthetically constructed) did, in fact, reflect natural conditions. Six different areas were established and delineated as distinct (i.e., stream channel, flood plain, north-, west-, south-, and east-facing slopes). Cluster analysis indicated distinctness in the flood plain, stream channel, and north-facing slope stands, but clustering west-, south-, and east-facing slope stands were as one unit. Vegetatively speaking, these three areas were highly similar and support vegetation distinctly different from the other three locations.

The patterns exhibited when indicator species frequency values were plotted against the moisture gradient also substantiate that the established moisture gradient is realistic and that the indicator species chosen are good index plants of general moisture conditions.

The relationships noted between the P × F index and the niche width measurements indicate that the two express similar information in terms of species importance in a system. Their correlation to each other is positive and highly significant.

Diversity was shown to be highest on the slopes and negatively correlated to moisture (i.e., as moisture increases diversity decreases) (Fig. 11). It is felt, however, that the diversity data would have been more meaningfully in-

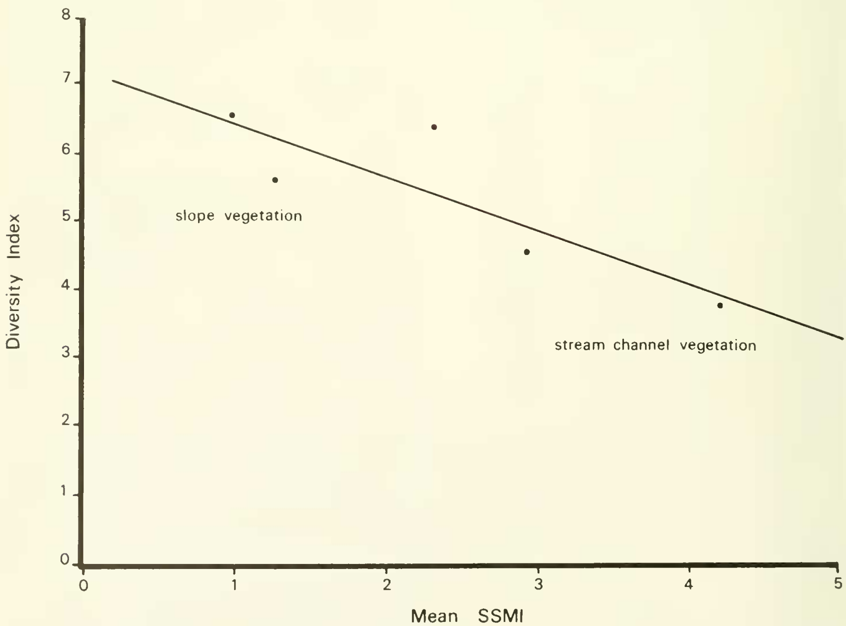

Fig. 11. Regression analysis of relationship between DI and SSMI.

terpreted if other environmental parameters (i.e., disturbance, etc.) had been measured. Regression analysis of DI vs. SSMI exhibited a negative correlation at .001 level of significance and had an r^2 value of .74.

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